PARTICLE SIZE DISTRIBUTION ANALYSIS OF MARS LANDER SITES :
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Particle size distribution (PSD) data has traditionally been employed to provide a first-order measure of the population of fragments observable on planetary surfaces[1] Commencing with the Surveyor lunar landers in the 1960's, and culminating with the Viking Mars landers of the 1970's, detailed measurements of the size frequency distribution of particles observed in lander images has been accomplished with variable success [1-7]. Specifically, if one's goal is to ascertain the provenance of the population of fragments larger than a few centimeters in diameter at a planetary surface as a means of inferring the geologic history of the region, as well as for documenting the dominant surface processes acting on the surface, then the results achieved to date are mixed. Enticing models for the geologic history of the Viking lander sites (hereafter VL) on Mars have been developed on the basis of PSD data augmented by particle shape and morphology statistics; indeed, a synoptic analysis of the geology of the VL sites by Sharp and Malin [11] treats the significance of the size frequency data very lightly and relies instead on various visual indicators toexplain the origin of the materials observed. Careful analysis of the materials at the VL sites, with emphasis on the physical properties of those in the nearfields (~ 80 m^2), was conducted by Moore and colleagues [7] Most recently, Golombek and Rapp [4]and Crumpler [3] have re-examined the VL site size and spatial frequency data for fragments in the near and far fields. Both of these latest considerations have suggested that exponential distributions best describe the PSD's for the VL sites, but fail to explainthe physical significance of this finding. Malin [5,6]demonstrated that the exponential distribution is mathematically well-suited for describing PSD data for the VL sites, as well as for Earth analogues (i.e., Antarctic dry valleys, Icelandic catastrophic flood deposits, etc.), and interpreted the exponential character of the PSD's for the surface of Mars in the context of the sorting mechanisms involved. Here, we propose an alternate basis for interpreting the formation, emplacement, and modification history of the local regions of Mars sampled by the Viking landers on the basis of particle size frequency data measured from specially selected VL images. In this case, we have employed a different approach for interpreting the PSD's for the martian surface in order to maximize the physical significance of information pertaining to the sorting process, which can be responsible for critical aspects of any fragment size distribution. Given the local evidence for impact cratering at both VL sites (i.e., small, simple craters within the field of view of the VL-1 site, and reasonable proximity of the VL-2 site to the complex crater Mie [1,11]) and the role of sorting and comminution in the ejecta emplacement process [10], the approach taken here was selected to focus attention on the physics of the emplacement process as it can be gleaned from PSD data. Terrestrial analogue sites were selected, imaged, measured, and analyzed by Garvin and Mouginis-Mark using methods as similar to those achieved by the Viking landers on Mars as possible [1,6]. Study sites within the phreatomagmatic ejecta at Halemaumau (Hawaii), the weathering-modified lava flows at the summit of Mauna Kea (Hawaii), and elsewhere were measured using a combination of VL-like imaging geometries, nadir viewing imaging, and *in situ* size analysis methods [6], all for surface areas approximately the same as those sampled by the Viking Landers (< 80 m^2). Although these data were collected and analyzed in the early 1980's, they have only been re-examined recently in the context of their possible utility as ground control sites for interpreting the fragment population that will observed at the Mars Pathfinder landing site (MPLS) in July of 1997.

Garvin et al. [1,2,6] exhaustively measured over 500 fragments larger than 2 cm in any linear dimension in the near fields of the VL sites. In addition, for each fragment, an estimate of the sphericity (i.e., a measure of "shape"), form, angularity, pitting geometry, degree of burial, fracture pattern, and other binary rock morphology attributes was recorded [1]. Clustering analysis of the entire set of rock morphometry and morphology parameters tabulated by Garvin and colleagues revealed sub-populations of fragments on the basis of size and surface texture parameters [1,6]. Furthermore, Garvin and colleagues suggested that differing degrees of primary sorting during fragment emplacement could explain some of the observed differences between the two PSD's. Sediment size analyis studies for arid regions pioneered by Bagnold [9] and refined by Bagnold and Barndorff-Nielsen [13] promoted the method of Hyperbolic-log distribution analysis (HLD). In this hybrid particle size distribution analysis method, emphasis is placed (mathematically) on the tails of the distribution, in order to focus upon issues of sorting. In effect, the HLD approach provides an extremely robust distributional analysis approach that includes as end-members the Normal (Gaussian) and Exponential distributions. Most simply, the HLD is defined as that in which the log probability function is a hyperbola, just as that for the Normal distribution is a parabola [12]. In other words, in log (probability density) versus log (size) space, the HLD is represented by a simple hyperbola parameterized in terms of four variables; of these, the most traditional is µ which corresponds to log of "peak diameter", and Ã which corresponds to the mode point or as the "typical log particle size". A scaling parameter _ and a sorting parameter

(†), which is essentially the curvature of the hyperbola at the mode point, can also be defined. Of most interest in terms of interpreting the sedimentology of a particle size dataset are the sorting (†) parameter, as well as the kurtosis K and the skewness S, both of which can easily be computed in terms of the basic parameters which control the HLD. Christiansen and Hartmann [8,12]have described how to apply HLD analysis methods to interpret particle size frequency data in terms of emplacement processes. They define a log-hyperbolic shape triangle which is parameterized in terms of the kurtosis and skewness values as derived from the best-fitting hyperbolic-log distribution to the raw particle size data. This log-hyperbolic shape triangle can be used to quantitatively consider the net effects of erosion and depositionon a population of fragments. We seek to use the HLD approach to consider both emplacement dynamics and environmental discrimination for the VL sites in comparison with simple terrestrial analogues (Halemaumau phreatomagmatic ejecta, Mauna Kea summit eroded lava flows, etc.). From a re-analysis of the VL site near field populations measured by Garvin et al. [1], we find that the VL-2 site is more poorly sorted than the VL-1 site, with a factor of two difference in the † parameter. The mode point and typical log particle size for the VL-2 nearfield is larger by several cm's than that derived for the VL-1 landing site. When the Viking sites are compared to the phreatomagmatic ejecta at Halemaumau, one observes fundamental differences suggesting that, at best, only a small fraction of the VL-1 population could be explained by simple, one-stage explosive fragmentation (i.e., the dominant process responsible for emplacing the Halemaumau ejecta fragments). We restricted our analysis of terrestrial analogue sites to areas no larger than the nearfield sample areas at the VL sites and thus excluded many of the larger fragments that are observed. When we compared the VL-2 site nearfield population with that observed at several sites at the summit of Mauna Kea (i.e., eroded lava flows), it is readily apparent that the eroded Mauna Kea block fields are better represented by a Laplace distribution than the positive hyperbolic distribution of the VL-2 population. This finding strongly argues against an in situ erosion process as the primary mechanism responsible for the nearfield fragment population at the VL-2 site. The greater degree of sorting at VL-2 in relation to VL-1 suggests the dominance of a single, higher-energy emplacement process at VL-2, perhaps involving distal Mie ejecta. The scale parameter _ for VL-1 most closely matches values for this parameter derived from measurements of simple lunar impact crater ejecta on the Moon (Cintala et al. [10]), and could be an indication that a subpopulation of relatively pristine ejecta exists at the VL-1 site. At present, we are modelling the nearfield fragment populations at the VL sites on Mars using the log-hyperbolic shape triangle approach suggested by Christiansen and Hartmann [12] in order to estimate the significance of in situ erosion at both sites. When Mars Pathfinder landing site particle size data becomes available, we plan to compare HLD analyses of the VL sites to those derived for the Pathfinder nearfield.

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